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OPTIMIZATION OF FILLET STRESS CONCENTRATION UNDER COMBINED LOADING

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Abstract: For shafts there are typically four failure modes taken into consideration during design, these are; maximum allowable stress, fatigue, deflection and critical speed. Shafts are typically loaded by three different load types; axial, bending and torsion separately or more generally in combinations. In practical shaft design we have abrupt diameter changes where a fillet is applied. For fillets we don't have infinite stresses but a stress concentration described by the stress concentration factor. The stress concentration factor is typically available in charts in textbooks. The charts are given for circular fillets and for the three different loading situations separately. Many charts are based on experimental results from photo elasticity. The typical procedure for a combined load case is to find the maximum stress resulting from each loading and from these maximum values calculate a reference stress (e.g. von Mises). This is done although the maximum stress is not found in the same point for the different load cases. Using this procedure we obtain a conservative estimate of the maximum stress. Structural optimization is a mature science and optimization has been performed on shafts, but the result of optimization has had limited impact on the practical shaft design. Also very few references are found with optimization of shafts for combined load cases. The stress concentration evaluation is in the present research performed using the FE method. For a successful application of shape optimization a couple of points are important. The main aspect is that the shape (with the high stress) parameterization is done separately from the design domain FE meshing, i.e. the nodal position in the FE mesh should not be used as design variables. The shape can be described either analytically or numerically. Which methods selected is not important for a successful optimization. In the present research we use the ANSYS program and utilize the harmonic elements. This allows for 2D axisymmetric models that can handle the non-axisymmetric loads or out of plane loading associated with bending and torsion. The harmonic elements can also handle the in-plane loading associated with axial load so the same model can be used for all three load cases.